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VEHICLE WEIGHT REDUCTION STUDY

by

Aluminum Company of America
Automotive Marketing Division

MARCH 1981

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HGIHWAY TRAFFIC SAFETY ADMINISTRATION
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16. Abstract

This report studies the potential for primary weight reduction of a 1979 Oldsmobile Omega X-body four-door sedan, by substituting aluminum components for iron and steel components where suitable. A secondary weight reduction is mentioned but is not detailed. This secondary weight saving is due to the fact that smaller and lighter supporting structure may be employed because of the reduced primary weight.

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PREFACE

This report was completed under Contract DTRS-57-80-P-81025 for the Department of Transportation, National Highway Traffic Safety Administration Office of Research and Development. The study was initiated to evaluate the weight saving possible in a General Motors "X" body by using aluminum. All practical applications and substitutions were considered.

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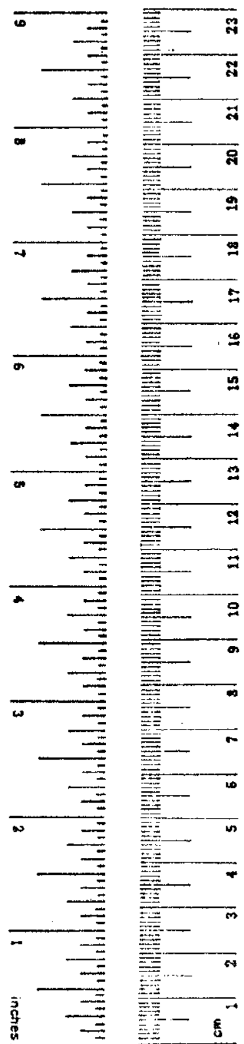
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

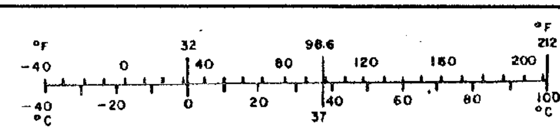
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The parts studied for weight reduction have been kept in the groupings adopted in a teardown study of a 1979 Oldsmobile Omega X-body 4-door sedan ("Oldsmobile Omega X-Body Baseline Weight Data," Report DOT-HS-805-212, Nov. 1979). All parts which can be made and joined in aluminum with existing technology were considered. The alloy, method of fabrication, estimated weight and weight savings are listed in Tables I and II.

Where aluminum has unique, advantageous characteristics or where processing differences bear a need for description, separate discussions are supplied. With each recommendation, the contributors feel the recommended aluminum substitutions are feasible and practical.

Reference: "Oldsmobile Omega X-Body Baseline Weight Data", by South Coast Technology, Report No. DOT-HS-805-212, U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C., November, 1979.

2. RESULTS

Total vehicle weight of the 1979 Omega is 2702 pounds. Of this total, 1,465 pounds of iron and steel components were selected as suitable for aluminum substitution, Table II. 133 pounds of the 2,702 pound total is already aluminum.

The South Coast Technology Report selected areas and gave component and total weights. This format was followed in Tables I and II with the summary weights being shown in Table I.

From Table I, 689 pounds of aluminum were substituted for 1,465 pounds of steel and iron. This substitution saves 776 pounds for a 53% weight saving of the parts considered. If no secondary weight saving is considered, the car weight will be reduced to 1,926 pounds for a 29% overall saving.

When secondary weight saving is taken as 50% of the primary, total weight saving will be (776 plus 388) 1,164 pounds. The total vehicle weight will then be 1,538 pounds for a 43% overall weight saving.

TABLE I. WEIGHT SAVING BY ALUMINUM SUBSTITUTION

AREA	WEIGHT OF PARTS CONSIDERED (LBS) STEEL & IRON	ALUMINUM	WEIGHT SAVED
Body	846.0	337.0	469.0
Frame	35.0	17.5	17.5
Front Suspension	45.3	26.3	19.0
Rear Suspension	51.2	27.4	23.8
Brakes	46.2	26.0	20.2
Engine	218.0	108.0	110.0
Transaxle	41.1	17.8	23.5
Fuel/Exhaust	29.9	12.5	17.4
Steering	11.9	5.5	6.4
Wheels/Tires	107.0	52.9	54.1
Cooling System	15.5	9.3	6.2
Bumpers	18.0	9.0	9.0
TOTALS	1,465	689	776

TABLE II. CANDIDATE PARTS AND WEIGHT REDUCTION

	Qty. per car	Total Weight per car (lbs.)	Material to be Replaced	FAB	Thickness (in.)	Aluminum Alloy	Thickness (in.)	FAB	Total Weight per car (lbs.)	Weight Saving (lbs.)	% Weight Saving	Comments
Body												
A. Hood											69	
Outer Panel	1	21.75	steel	stamp	0.034	6010	0.028	stamp	6.16	15.59		
Inner Panel	1	16.75	steel	stamp	0.031	6009	0.031	stamp	5.76	10.99		Redesign Required
Hinges	2	1.38	steel	stamp	0.156	6XXX	0.156	stamp	0.47	0.91		
Latch	1	2.00	steel	stamp	0.109	6XXX	0.109	stamp	0.69	1.31		
B. Rear Deck Lid											69	
Outer Panel	1	18.25	steel	stamp	0.037	6009	0.028	stamp	4.75	13.50		
Inner Panel	1	13.75	steel	stamp	0.031	6010	0.031	stamp	4.73	9.02		Redesign Required
Latch & Lock	1	1.38	steel	stamp		6XXX		stamp	0.69	0.69		
C. Front Fender											65	
Fender Panel	2	20.00	steel	stamp	0.034	6010	0.034	stamp	6.88	13.12		
Trim	2	1.12	s.steel	stamp		5252			0.56	0.56		
D. Body Valence & Dam											66	
Support Panel	1	0.59	steel	stamp	0.036	6XXX	0.036	stamp	0.20	0.39		
E. Front Door											61	
Inner Panel	2	38.00	steel	stamp	0.042	6009	0.042	stamp	13.07	24.93		
Outer Panel	2	21.50	steel	stamp	0.035	6010	0.035	stamp	7.40	14.10		
Lock & Latch	2	5.12	steel	stamp		6XXX		stamp	2.47	2.65		
Hinges	2	2.75	steel	stamp	0.194	6XXX	0.270	stamp	1.32	1.43		
Safety Beam	2	12.50	steel	stamp	0.092	6010	0.125	stamp	5.84	6.66		
Lower Molding	2	1.12	s.steel	stamp	0.029	5252		stamp	0.54	0.58		
F. Rear Door											61	
Inner Panel	2	23.30	steel	stamp	0.031	6009	0.031	stamp	8.02	15.28		
Outer Panel	2	16.50	steel	stamp	0.036	6010	0.036	stamp	5.68	10.82		
Lock & Latch	2	4.30	steel	stamp		6XXX		stamp	2.07	2.27		
Hinges	2	2.19	steel	stamp	0.179	6XXX	0.250	stamp	1.05	1.14		
Safety Beam	2	9.00	steel	stamp	0.061/0.043	6010		stamp	4.50	4.50		
Lower Molding	2	0.88	s.steel	stamp	0.029	5252		stamp	0.43	0.45		
G. Pillar Hinges											52	
Front	2	3.25	steel	stamp	0.213	6XXX	0.300	stamp	1.57	1.68		
Rear	2	2.62	steel	stamp	0.179	6XXX	0.250	stamp	1.26	1.36		

TABLE II. CANDIDATE PARTS AND WEIGHT REDUCTION (CONT.)

	Qty. per car	Total Weight per car (lbs.)	Material to be Replaced	FAB	Thickness (in.)	Aluminum Alloy	Thickness (in.)	FAB	Total Weight per car (lbs.)	Weight Saving (lbs)	% Weight Savings	Comments
1. Body (cont.)												
H. Exterior Trim											62	
Air-Intake Grille	1	4.31	steel	stamp	0.036	6010	0.036	stamp	1.48	2.83		
Wind. Wip. Links	1	2.09	steel	stamp		6XXX		stamp	1.01	1.08		
Pr. End Panel Supp.	1	0.72	steel	stamp	0.060	6XXX	0.084	stamp	0.35	0.37		
Roller Panel Mldg.	2	4.00	s.steel	stamp	0.025	5252	0.025	stamp	1.38	2.62		
Panel, Rear Comp Top	1	1.00	steel	stamp	0.028	6XXX	0.050	stamp	0.49	0.51		
Rear Wheel Mold	2	1.25	s.steel	stamp	0.030	5252	0.028	stamp	0.43	0.82		
I. Front Seat											50	Design modification probable. Casting may be feasible.
Frame	1	29.50	steel	stamp	0.030	6009		stamp	14.75	14.75		
J. Rear Seat											52	
Base	1	(5.00)[a]	steel	stamp		6XXX		stamp	2.38	2.62		
Back	1	(4.00)[a]	steel	stamp		6XXX		stamp	1.90	2.10		
K. Body Panels											52	
Radiator Brace	2	2.31	steel	stamp/weld	0.080	6XXX	0.080	stamp/weld	0.79	1.52		
Quarter Panel Outer	2	26.94	steel	stamp/weld	0.032	6010	0.044	stamp/weld	12.74	14.20		
Rear Wheel Well	2	21.50	steel	stamp/weld	0.032	6009	0.044	stamp/weld	10.17	11.33		
Tail Light Panel	1	6.00	steel	stamp/weld	0.035	6XXX	0.049	stamp/weld	2.89	3.11		
Roof Outer Panel	1	33.31	steel	stamp/weld	0.035	6010	0.049	stamp/weld	16.04	17.27		
Roof Inner Ribs	Lot	16.75	steel	stamp/weld	0.032/0.035	6010	0.045/0.035	stamp/weld	8.00	8.75		Cross-rib redesign probable
Firewall	1	7.94	steel	stamp/weld	0.035	6009	0.049	stamp/weld	3.82	4.12		
Sill	2	32.19	steel/HSLA	stamp/weld	0.040	6010	0.044	stamp/weld	12.30	19.89		
Floor Panel	1	56.44	steel	stamp/weld	0.032	6009	0.045	stamp/weld	27.30	29.14		
"A" Post, Pillar	2	23.06	steel/HSLA	stamp/weld	0.040/0.048	6009	0.053/0.069	stamp/weld	11.33	11.73		
"B" Post, Pillar	2	19.12	steel	stamp/weld	0.032/0.048	6009	0.037/0.058	stamp/weld	6.58	12.54		
Rear Shelf	1	12.06	steel	stamp	0.035	6009	0.049	stamp	6.35	5.71		
Center Support (fr.)	1	1.62	steel	stamp	0.050	6010	0.070	stamp	0.78	0.84		
Remaining Body Panels		294.87	steel	stamp	various	6XXX		stamp	147.44	147.43		50% weight savings probable
2. Frame											50	
A. Cradle	1	35.00	steel	stamp/weld	0.080/0.095	5454		stamp/weld	17.50	17.50		
3. Front Suspension											43	
Lower Control Arm	2	10.50	steel	stamp	0.110	5454	0.165	stamp	5.42	5.58		
Steering Stop Bracket	2	1.44	steel	stamp	0.125	6XXX	0.125	stamp	0.50	0.94		
Knuckle (Upright)	2	20.00	iron	cast		6061		forge	12.00	8.00		Permanent mold casting also feasible
Spring Seat	2	2.62	steel	stamp	0.077	6XXX	0.108	stamp	1.26	1.36		
Stabilizer Bar	1	9.75	steel	drawn	0.870⌀	6061	1.22⌀	rod	6.60	3.15		
Brake Rotor Shield	2	1.00	steel	stamp	0.037	5454	0.052	stamp	0.48	0.52		

TABLE II. CANDIDATE PARTS AND WEIGHT REDUCTION (CONT.)

	Qty. per car	Total Weight per car (lbs.)	Material to be Replaced	FAB	Thickness (in.)	Aluminum Alloy	Thickness (in.)	FAB	Total Weight per car (lbs.)	Weight Saving (lbs)	% Weight Savings	Comments
4. Rear Suspension											46	
Axle Beam	1	27.12	steel	stamp	0.175	5454		stamp	13.56	13.56		
Control Arm	2	6.06	steel	stamp	0.165	5454	0.330	stamp	4.17	1.89		
Spring Perch	2	4.25	steel	stamp	0.125	5454	0.175	stamp	2.05	2.20		
Anti-Roll Bar	1	8.22	steel	drawn	0.812Ø	6061	1.07Ø	rod	4.93	3.29		
Track Bar	1	3.81	steel	stamp	0.093	6XXX	0.130	stamp	1.90	1.91		
Trailing Arm Brkt.	2	1.75	steel	stamp	0.092	6XXX	0.125	stamp	0.82	0.93		
5. Brakes											44	
Calipers	2	14.00	iron	cast		6061		forge	7.60	6.40		
Drums	2	14.00	iron	cast		355		cast	9.60	4.40		Iron insert required
Backing Plate	2	4.19	steel	stamp	0.100	6009	0.140	stamp	2.02	2.17		
Park Brake Pedal & Lock	1	2.50	steel	stamp	0.090	6009	0.126	stamp	1.20	1.30		
Brake Power Assist	1	8.25	steel	stamp	0.055	5182	0.077	stamp	3.97	4.28		
Pedal Assembly	1	1.90	steel	stamp	0.375	6XXX		stamp	0.95	0.95		
Pedal Mount-Brkt	1	1.38	steel	stamp	0.093	6XXX	0.093	stamp	0.69	0.69		
6. Engine											50	
Cylinder Head	2	49.00	iron	cast		355		cast	23.00	26.00		Ferrous guides and seats
Air Cleaner Assy	1	6.00	steel	stamp		5182		stamp	2.03	3.97		
Valve Cover	2	3.75	steel	stamp	0.045	5182		stamp	1.27	2.48		
Oil Pan	1	5.06	steel	stamp	0.045	5182	0.063	stamp	2.40	2.66		Special forming reqd
Engine Block	1	(125.00)[a]	iron	cast		355		cast	65.00	60.00		Iron sleeves and bearing caps.
P. Steering Pump	1	(8.00)[a]	steel	stamp		5182		stamp	4.00	4.00		
P. Steering Brkt	2	3.38	steel	stamp	0.200	5454	0.280	stamp	1.60	1.78		
Air Cond. Brkt	3	5.06	steel	stamp	0.193	5454	0.270	stamp	2.40	2.66		Forging possible
Fuel Pump Ht. Sh.	2	0.59	steel	stamp	0.027/0.090	5182	0.027/0.090	stamp	0.20	0.39		
Engine, Transmission Mounting Brkt	Lot	6.50	steel	stamp	various	5454		stamp	3.25	3.25		
Engine Vibration Mt.	3	(4.60)[a]	steel	stamp	various	5454		stamp	2.30	2.30		
Throttle Bracket	1	0.88	steel	stamp	0.078	5XXX		stamp	0.44	0.44		
7. Transaxle											57	
Valve Body	1	13.00	iron	cast		380		die cast	4.33	8.67		Spool valves of 6262
Valve Body Cover	1	2.44	steel	stamp	0.050	5182	0.050	stamp	0.83	1.61		
Fluid Pan	1	(2.64)[a]	steel	stamp/mold	0.047	5182	0.047	stamp	0.90	1.74		
Torque Converter	1	23.00	steel	stamp/mold	various	6009		stamp	11.50	11.50		Efficient fab procedure needed.

TABLE II. CANDIDATE PARTS AND WEIGHT REDUCTION (CONT.)

	Qty. per car	Total Weight per car (lbs.)	Material to be Replaced	FAB	Thickness (in.)	Aluminum Alloy	Thickness (in.)	FAB	Total Weight per car (lbs.)	Weight Saving (lbs.)	% Weight Savings	Comments
8. Fuel and Exhaust System											58	
Gas Tank	1	21.75	steel	stamp	0.036	5182	0.040	stamp	8.20	13.55		Form flanged and use adhesive bonds
Filler Neck, Vent	1	2.28	steel	drawn	1.250	3102		drawn	1.55	0.73		
Tank Straps	2	2.12	steel	stamp	0.090	6XXX	0.090	stamp	0.73	1.39		
Shields	3	3.75	steel	stamp	0.020	5454	0.040	stamp	2.00	1.75		
9. Steering											54	
Steering Wheel	1	(4.10)[a]	steel	stamp		6XXX		rod/sheet	2.05	2.05		Design modification probable
Pad	1	(0.53)[a]	steel	stamp/mold		6XXX		stamp/mold	0.18	0.35		
Jacket Assembly	1	2.56	steel	drawn		5182		stamp	0.88	1.68		
Shift Tube	1	1.20	steel	drawn		6XXX		rod	0.60	0.60		
Brackets	6	3.50	steel	stamp	various	5454		stamp	1.75	1.75		
10. Wheels/Tires											51	
Wheels	4	69.00	steel	stamp	0.100	5454		sheet	41.00	28.00		Forged wheels est. at 34 lbs.
Wheel Covers	4	17.00	steel	stamp	0.034	---	No Cover - Finished Wheel Surfaces -					
Spare Wheel	1	(14.00)[a]	steel	stamp		5454		stamp	8.40	5.60		
Bumper Jack Assy	1	7.00	steel	stamp	0.095/0.115	6XXX		stamp	3.50	3.50		
11. Cooling											40	
Radiator	1	15.50	brass	stamp/solder					9.30	6.20		Requires several different alloys
12. Bumpers											50	
E-A Units	4	18.00	steel	stamp/drawn		6009		stamp/drawn	9.00	9.00		

a Weight in ( ) is estimated steel or iron weight to be replaced

3. DISCUSSION

The examination of a disassembled vehicle gave the contributors a unique opportunity to study individual components and make recommendations as to process, alloy, temper and thickness in order to calculate part weight and weight saving. The combined automotive experience of the contributors is over one hundred years. All the recommendations are deemed to be feasible and practical.

Many of the parts studied are already being made in aluminum by foreign or domestic producers for reasons of weight saving or performance. Not all of these production parts are optimized by design and alloy for maximum weight saving.

This report makes the assumption that optimum designs, processes and alloys are used. For example, it is assumed that alloys 6009-T4 and 6010-T4 will receive an aging treatment in the primer bake cycle to reach 35 ksi and 45 ksi yield strengths respectively. These strengths match low carbon steels and some HSLA steels. Thickness for thickness substitutions are possible where denting or strength is the primary requirement and weight saving will be 63%.

Where other design criteria prevail, a separate discussion is supplied. Separate comments are also supplied for various processes. The comments on energy savings and recyclability are unique to aluminum. Specific references are given for each discussion.

Aluminum intensive automobiles have been and are being built but none by accepted mass production techniques. The alloys and processes described in this report would enable a manufacturer to build an aluminum intensive vehicle in mass production.

3.01 CORROSION

The aluminum alloys recommended for various applications in this report are used both painted and bare, depending on the location on the vehicle. They are alloys which have been proven on vehicles in service. By themselves, they are resistant to corrosion in the environment of streets and highways. When they are attached to dissimilar metals in continuously wet conditions, precautions need to be taken.

The precautions are detailed in the literature but, in general, the practice is to protect steel in a galvanic situation. If steel is well protected, aluminum cannot corrode galvanically. For maximum protection against corrosion, sealants to keep water out of the joint may be used.

References:

SAE Paper 750464 - Performance of Aluminum in Bimetallic Assemblies by King, Sowinski and Englehart

SAE Paper 760166 - Corrosion Performance of Painted Aluminum Steel Body Sheet by King and Englehart

3.02 COST

It is not practical for the contributors to calculate the actual cost of substituting an aluminum part for a steel part. Materials handling, forming and finishing costs are often unaffected by the change, but there is a material cost difference and there may be joining cost differences.

Using prices of this date (August, 1980), coiled aluminum heat-treated sheet at $1.10 per pound and coiled steel sheet at $.22 per pound*, the following two examples may be helpful:

For one square foot of final area, using equal thicknesses, 1.44 square feet of material must be purchased. There will be approximately 30% offal for trimmed material not included in the final part.

	Steel .032"(t)	Aluminum .032"(t)
Area	1.44 Sq Ft	1.44 Sq Ft
Weight	1.92 Lbs	.65 Lbs
Cost	$0.42	$0.71
Offal	.58 Lbs	.20 Lbs
Scrap Credit	$0.03 ($0.05/Lb)	$.10 ($0.48/Lb)
Net Material Cost	$0.39	$0.61
Net Weight	1.34 Lbs	.45 Lbs
Weight Saved	1.34 - .45 = .89 Lbs	
Material Cost Difference	$0.61 - 0.39 = $0.22	

Cost/Lb of Weight Saved -- $0.25

*Galvanized or coated sheet will increase this cost substantially.

For a stiffness constrained flat sheet part, aluminum would be increased in thickness by 44%. The cost per pound of weight saved will be:

	Steel .032"(t)	Aluminum .046"(t)
Area	1.44 Sq Ft	1.44 Sq Ft
Weight	1.92 Lbs	.94 Lbs
Cost	$0.42	$1.03
Offal	.58 Lbs	.28 Lbs
Scrap Credit	$0.03 ($0.05/Lb)	$0.14 ($0.48/Lb)
Net Material Cost	$0.39	$0.89
Net Weight	1.34 Lbs	.66 Lbs
Weight Saved	1.34 - .66 = .68 Lbs	
Material Cost Difference	$0.89 - 0.39 = $0.50	

Cost/Lb of Weight Saved -- $0.74

To these previously mentioned costs per pound of weight saved, the small incremental cost of additional joining materials (adhesives, pierce rivets, etc.) must be added. By the same procedure, the lower costs of supporting structures (less material such as smaller tires and springs and unneeded paint and corrosion protection) should be credited.

3.03 DESIGN

The typical engineering properties of the aluminum alloys used in the automobile industry and, particularly the ones in this report, are available as they are in steel. An engineer, with knowledge of these properties and the performance requirements of a component, can design a part in either aluminum or ferrous alloys. The advantage of aluminum is that it has one-third the weight of ferrous alloys in equal volumes; therefore, the theoretical weight saving of aluminum over steel in equal volumes, or thickness for thickness, is 63%.

The modulus of elasticity for steel is three times that of aluminum, so a steel member identical to one of aluminum will be three times stiffer. Flat panel stiffness, however, is a function of the product of the modulus and the thickness to the third power; therefore, an aluminum sheet need only be increased by 44% in thickness and will give a 50% weight saving. Formed sheet members may be increased in depth or be more closely spaced or be made slightly thicker in aluminum so that overall performance is similar to steel while approaching the theoretical weight saving.

In Table II, where weight saving is shown as less than 63%, it is implied that stiffness or fatigue is a requirement and aluminum thickness must be increased for equal performance or, as might be noted under "comments", redesign is required.

References: Aluminum Association T8 - Design for Aluminum -- A Guide for Automotive Engineers

SAE Special Publication AE-4 - Fatigue Design Handbook

SAE Paper 770200 - Structural Characteristics of Aluminum Body Sheet by Rolf, Sharp and Stroebel

SAE Paper 770269 - Structural Design Considerations for Aluminum Bumpers by Sharp, Peters and Weiss

SAE Paper 780140 - Structural Performance of Aluminum Bumpers by Sharp, Jombock and Shabel

SAE Paper 780248 - Aluminum Structural Castings Result in Automobile Weight Reduction by Hatch and Jorstad

SAE Paper 790164 - Minimizing the Weight of Aluminum Body Panels by Rolf, Sharp and Herbein

3.04 ENERGY

The lifetime energy savings possible in an automobile through the use of aluminum are considerable. Not only is there an initial weight saving, but secondary weight savings are possible because of reduced sprung weight and inertia forces. The following statements are taken from Aluminum Association Report T12 - Use of Aluminum in Automobiles -- Effect on the Energy Dilemma, 3rd Edition, April 1980, Page 18.

- Each pound of weight reduction in a properly redesigned and reoptimized car saves about 1.1 gallons of gasoline in the car's 100,000 mile lifetime.

- Each pound of aluminum reduced weight directly by an average of 1.5 pounds compared to steel parts, and indirectly by about 0.75 pounds, for total weight reduction of 2.25 pounds.

- Each pound of aluminum saves about 2.5 gallons of gasoline during a car's lifetime.

- 118 pounds of aluminum in the average 1979 car can save up to 265 pounds of weight and about 290 gallons of gasoline in the car's lifetime.

- 200 pounds of aluminum would save about 450 pounds and about 500 gallons in a car's lifetime.

- Aluminum in 1979 U.S. model cars can save as much as 2.9 billion gallons in their service lifetime.

- 200 pounds in the average new car would save 5 billion gallons of gasoline based on a 10-million car fleet.

- Aluminum in cars is cost efficient; the material premium for aluminum over steel for each gallon of gasoline saved is about 14 cents.

- Aluminum in cars is energy efficient on a lifetime basis.

- The energy saving from reduced gasoline consumption is nearly 5 times greater than the energy required to produce a pound of aluminum.

- Lifetime energy requirements for cast aluminum parts made from recycled metal are less than one-fourth the lifetime energy requirements of cast iron parts.

- On a lifetime basis, wrought aluminum parts use only about one-third as much petroleum (production energy and gasoline) as wrought steel parts.

- On a lifetime basis, wrought aluminum parts use less petroleum than plastic SMC parts.

- The very real potential for increased recyclability will make aluminum even more energy efficient.

3.05 FORMING

Stamped aluminum parts are formed on the same presses and at line speeds similar to those for steel. The drawability of typical shallow drawn aluminum auto body panels will be equal to draw-quality steel; however, since stretchability (ductility) of aluminum is less, different forming guidelines are used to avoid fractures by distributing strains over larger areas. Lubrication during forming and the use of contoured blanks can be important in promoting smooth metal flow into the die while minimizing concentrated stretch. The forming tools for aluminum stampings are similar to those used for steel and they will, in fact, form steel parts although it may be necessary to change tool contours slightly to provide for different spring-back characteristics.

Localized operations, such as bending, down-flanging, hemming and hole-flanging need to be considered with attention to the particular aluminum alloy. In some instances, such design details may need to be different than those used for steel.

In general, the cost of new production tooling, labor content for stamping, the rate of production and the recovery percentage of good parts are essentially identical for aluminum and steel parts. In consideration of alternate materials, the feature that aluminum can be fabricated in the same production facilities with the same people is a highly positive factor.

Alloys 6009 and 6010 are recommended in this report for exterior body panels. Alloy 6010 in particular, is recommended where a high yield strength is needed to resist denting. These alloys are partially heat-treated (to the T4 temper) in a continuous operation at the aluminum sheet mill; this leaves them in a ductile state so that they may be formed. To attain the required strength levels, the formed part then must be heated to the vicinity of 400°F for thirty minutes to one hour (various combinations of time and temperature are possible). Since a primer bake that accomplishes these temperatures is often used, the heating need not be regarded as a separate operation attributable to the material.

The general characteristics for forming aluminum are widely discussed and available in literature from individual aluminum companies and the Aluminum Association.

References:

SAE Paper 780392 - Inter-relation Between Part and Die Design for Aluminum Auto Body Panels by Wolff

SAE Paper 780141 - Forming High Strength Bumpers from Aluminum Sheet by Blayden and Parnell

Aluminum Association T8 - Design for Aluminum -- Guide for Automotive Engineers

3.06 JOINING

Resistance spot welding is highly developed for steel and is widely used in automobile production lines. In most instances, aluminum may be spot welded in a similar fashion with similar equipment; however, there are two major differences. First, aluminum has three times the thermal and electrical conductivities of steel. Second, an aluminum spot weld has about one-half the strength of a steel spot weld.

Since approximately three times the current density is required to weld aluminum as compared to steel, equipment modifications may be required. Welding time, however, is only 4 cycles of 60 cycle current vs. 16 cycles for steel. Series welding (multiple spot welds made simultaneously) must be sequenced for aluminum but the total weld time remains constant due to the short cycle time. Alternate low energy techniques are available, such as adhesive bonding, mechanical clinching and metal piercing rivets.

The strength of aluminum assemblies can be increased by combining adhesives with spot welds (weldbonding) to equal or surpass the strength and fatigue life of spot welded steel components. Some subassemblies may be joined without spot welding by using adhesively bonded hem flanges.

Mechanical clinching is an available production technique and it, too, can be coupled with adhesives for additional strength and fatigue life. Metal piercing rivets can be used to join dissimilar metals as well as aluminum to aluminum and are easily inspected. Lastly, two old established techniques are available, arc welding and bolting.

In conclusion, when resistance spot welding of aluminum is a problem because of equipment or strength limitations, alternate techniques are available which take no greater production time; however, some equipment and design changes may be required.

References: SAE Paper 740078 - Adhesive Bonding of Aluminum Automotive Body Sheet by Minford and Vader

SAE Paper 750462 - Weld Bond and Its Performance in Aluminum Automotive Body Sheet by Minford, Hoch and Vader

SAE Paper 780396 - Joining of Aluminum Alloys 6009/6010 by Hoch

SAE Paper 780397 - Fatigue Performance of Aluminum Joints for Automotive Applications by Nordmark

Aluminum Association T8 - Design for Aluminum -- A Guide for Automotive Engineers

Aluminum Association T10 - Tentative Guide to Automotive Resistance Spot Welding of Aluminum

Aluminum Association T11 - Mig Spot Welding of Aluminum

Aluminum Association T17 - Weldbonding - An Alternative Joining Method for Aluminum Auto Body Alloys

3.07 MATERIALS HANDLING

The materials handling equipment in place for steel is suitable for aluminum. However, aluminum coils weigh only one-third as much as similar sized steel coils. In general, more attention must be paid to handling and transfer equipment to prevent scratching of the aluminum surface. Good housekeeping and elimination of sharp projections such as worn bolt heads or torn sheet metal also reduce damage to steel and aluminum when they are processed on the same production line. A thorough discussion of materials handling is detailed in the literature.

Reference: Aluminum Association Publication T16 - In-Plant Handling and Repair of Aluminum Auto Body Sheet

3.08 METAL AVAILABILITY

Within the period of 1985 to 1995 considered by this report for aluminum applications, adequate metal supplies can be made available. An aluminum intensive vehicle, as with other vehicles, would take from three to five years to reach production from the initiation of the design. The three to five year lead time is enough to bring additional aluminum fabrication facilities into being if they are required.

3.09 PAINTING

Existing paint systems, primarily designed for steel, have been found to be adequate for aluminum. Technology has been developed to paint aluminum and steel at the same time.

In some instances, such as aluminum air cleaner trays and lids, corrosion is not a problem and painting has been eliminated. Floor space and energy is saved.

Reference: SAE Paper 740079 - Finishing Considerations for Aluminum Body Sheet Alloys by Baker and McGinnis

3.10 RECYCLING

The aluminum alloys specified in this report are completely recyclable into themselves or similar alloys. They are particularly recyclable into castings such as pistons, blocks and manifolds. The energy required for recycling into molten metal is only one-twentieth that of the primary metal.

There is an established recycling industry, from junkyard to secondary smelter, that insures that metal lost is infinitesimal. No new technology is required. In addition, the increased value of the junk car, because of its aluminum content, makes recycling economically attractive.

Reference: "Recycling" - Journal of Metals; February 1980

Aluminum Association T12 - Use of Aluminum in Automobiles -- Effect on the Energy Dilemma

3.11 REPAIR

On-Line

On-line repair of aluminum body sheet panels is neither more difficult nor more time consuming than for steel. Nicks, scratches, "in dings" and "out dings" can be bumped, filed and ground to final smoothness with the same labor and in the same time as for steel.

Field

Aluminum and steel sheet metal components not severely damaged may be straightened, bumped and sanded with identical equipment and skills. Body repair shops typically use plastic fillers to recreate the original surface. These fillers are compatible with aluminum, steel and plastics. Under skilled hands, the repaired surface is indistinguishable from the original, regardless of substrate.

Reference: Aluminum Association Publication T16 - In-Plant Handling and Repair of Aluminum Auto Body Sheet

Aluminum Association Publication T15 - Repair of Aluminum Automotive Sheet by TIG and MIG Welding

3.12 SECONDARY WEIGHT SAVINGS

In this report, no credit has been taken for secondary weight saving. Secondary weight saving is weight which can be saved in the supporting structure and drive train (engine, transmission, suspension, sub-frames, and wheels) because it no longer has to support or propel so much weight. Springs, shock absorbers, axles, brakes, wheels and tires may be made smaller and lighter for a lighter weight vehicle. Energy abosrbing systems behind the bumpers and reinforcements as well as the bumpers and reinforcements themselves may be made smaller and lighter. A counterbalance spring for the hood or rear deck may be reduced in weight by 50 to 60 percent or removed entirely. For equal performance, a smaller engine and transmission can be used and, with less fuel consumption, a smaller fuel tank and fewer gallons need be carried.

Some automobile companies have indicated that secondary weight saving can be as high as 1.6 times the primary weight saving. The contributors have chosen the more conservative estimate of 50% given in Aluminum Association Report T12. The final vehicle weight will then be 1,538 pounds.

Reference: Aluminum Association T12 - Use of Aluminum in Automobiles -- Effect on the Energy Dilemma